United States
Department of
Agriculture

Forest Service

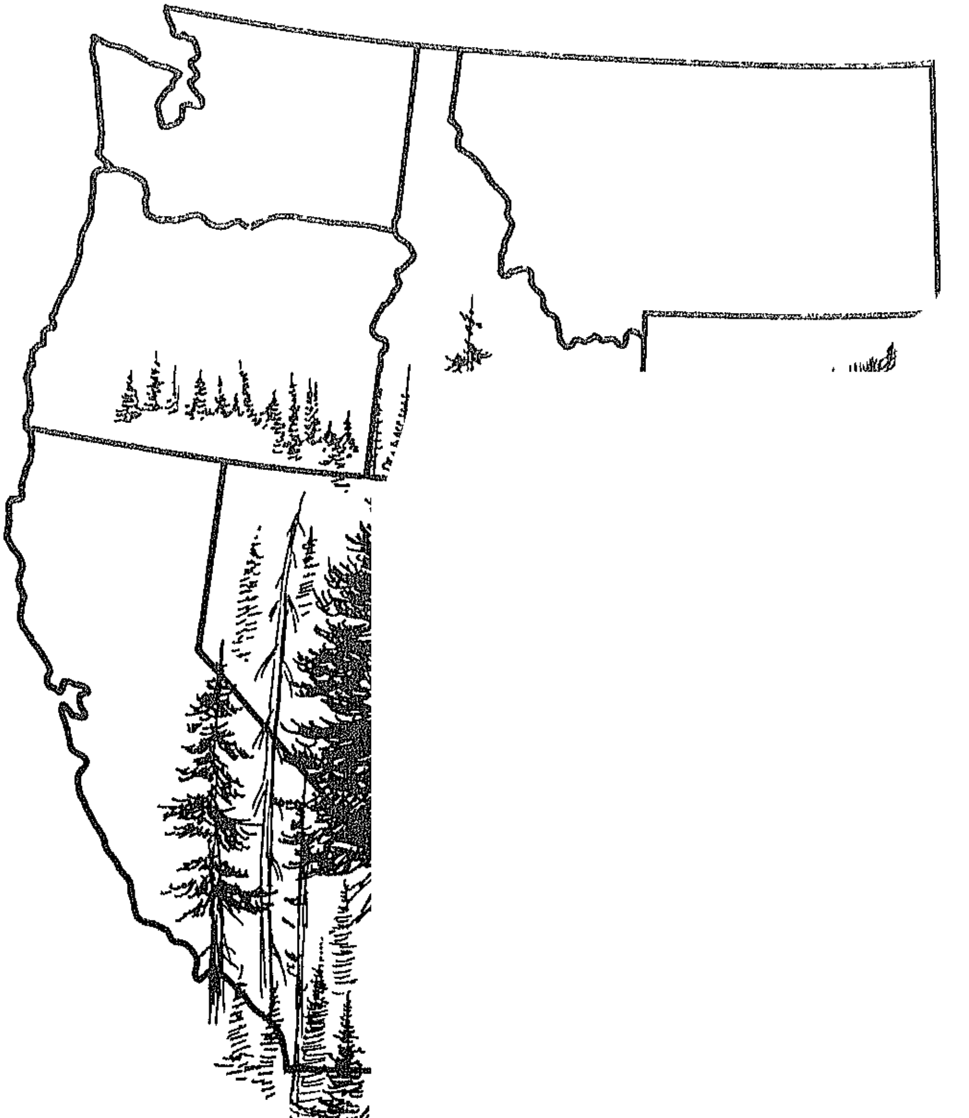
**Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401**

General Technical
Report INT-125

April 1982

The Dead Softwood Timber Resource and Its Utilization in the West

David P. Lowery



THE AUTHOR

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RESEARCH SUMMARY

The commercial forest land of the West contains dead timber in large quantities that increase each year because of new insect and disease outbreaks. The salvage and utilization of these dead trees is dependent to a large extent on the deterioration that occurs prior to harvesting.

Wood deterioration progresses at an accelerated rate after the tree's death and is affected by various wood, climatic, and biological factors. The longer the dead trees are exposed to the degrading elements, the lower the quantity and quality of usable material that can be recovered. Prompt salvage of dead trees is necessary if the greatest values are to be obtained.

Studies indicate that dead trees and logs can be used for essentially the same purposes as green trees of the same species: lumber, house logs, posts, poles, firewood, and in the production of pulp, paper, and particle board. The use of dead trees in plywood manufacture is often restricted.

This report summarizes the available information on the deterioration and utilization of the western softwoods.

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INTRODUCTION

A few years ago birds, animals, and a few artists were about the only ones interested in dead trees. Birds and animals use dead trees for dens, nests, resting, and observation posts. Artists see beauty in these lifeless forms and in their difference from the surrounding forest But today timber owners, land managers, and the forest products industry are interested in harvesting and using dead trees.

Since about 1970 timber supply and demand curves have been drastically altered from their projected patterns due in part to continual erosion of the commercial forest land and increased demand for lumber and other wood products. The change of land from timber production to roads, utility rights-of-way, wilderness, and housing subdivisions has reduced the number of acres available to supply our timber needs. A steadily increasing population requires more and more wood products to satisfy its demand for housing and other necessities. The future wood supply depends, to a certain extent, on improved utilization and processing procedures. This could be done by using all parts of the harvested sawtimber-size trees, or by using the smaller, presently unmerchantable trees and down or standing dead trees that often make up the bulk of the postharvest residue.

The overmature, unmanaged forest stands of the West have been subjected to repeated attacks by insects and diseases (fig. 1). The resulting dead trees, scattered throughout the forest, are often left in the woods after harvesting as the major component of the logging residue. The increased use of these dead trees would extend the timber supply.

This report assembles available information describing the dead timber resource, summarizes research on its utilization, and discusses factors to be considered in processing this material.

Figure 1.—The forests of the West contain many trees killed by insects and disease.

THE DEAD TIMBER RESOURCE

The volume of dead timber in the Nation's forests is enormous and estimates as the exact amount are quite variable. Perhaps the best procedure for obtaining a reliable estimate is to use annual data of trees killed by insects, disease, fire, or windthrow. In 1976, mortality on the National Forests' commercial timberland amounted to over 1 billion cubic feet (28.3 million m^3) of growing stock, including 4 4 billion board feet (1.263 million m^3) of sawtimber. This volume is equivalent to slightly more than one-third of the 1976 softwood removal from National Forest lands (USDA 1977). The annual mortality on the commercial forest land on western forests is shown in table 1.

Table 1.—Annual tree mortality for hardwoods and softwoods on the commercial timberland of the public and private commercial forests of the Western States, 1976 (source. USDA, Forest statistics of the U.S, 1977)

State	Growing stock		Sawtimber	
	M ft³	*M m³*	*M bd.ft.*	*M m³*
Oregon	427,500	12 098	1,979,400	568 088
Washington	345,400	9 775	1,696,200	486 809
California	143,000	4 047	791,200	227 074
Idaho	123,365	3 491	561,172	161 056
Montana	130,063	3 681	460,066	132 039
Utah	53,526	1 515	191,387	54 928
Wyoming	42,055	1 190	152,608	43 299
Colorado	91,943	2 602	328,536	94 290
Arizona	15,133	428	68,265	19 592
New Mexico	36,127	1 022	134,727	38 667
Nevada	1,727	49	9,419	2 703
South Dakota	3,791	107	16,645	4 777
TOTAL	1,413,630	40 005	6,389,625	1 833 822

Although all species are susceptible to insect and disease attack, the western species most attacked are Douglas-fir (*Pseudotsuga menziesii* [Mirb] Franco), lodgepole pine (*Pinus contorta* Dougl.), western white pine (*Pinus monticola* Dougl.), ponderosa pine (*Pinus ponderosa* Laws.), and the true firs (*Abies* sp.). Bark beetles are responsible for most of the dead trees. In Montana, northern Idaho, and northeastern Oregon, the mountain pine beetle (*Dendroctonus ponderosa* Hopk.) is killing large numbers of lodgepole and western white pine trees. Catastrophic losses that result in concentrations of dead trees can become a focal point for salvage efforts. However, much of the endemic mortality on the National Forests occurs in unroaded areas, inaccessible to logging. In addition, the mortality is scattered over large areas, which hinders prompt detection and removal. Theoretically, if all the mortality could be salvaged, the annual timber supply could be increased by about 45 percent; but only about 28 percent of the dead timber is both accessible and marketable, and only 10 percent is salvaged each year.

Depending on climate and environmental conditions, dead trees may be a major component of the green timber stand at the time of harvest. West of the coastal mountain ranges, the deterioration rate of downed trees by fungal action is often slowed due to the extremely wet conditions East of the Cascades and extending into Montana, the lack of moisture and the relatively low ambient temperature at the higher elevations act to restrain the degrading process. As a result, dead timber accumulates in the western forests and, unless removed with the green trees, becomes a highly visible segment of the postharvest residue (fig 2). Figure 3 shows those factors that affect the volume of dead timber in the western forests.

Figure 2.—Standing and down dead trees are often not removed during harvesting.

Deterioration of Dead Trees

The value of dead timber and its suitability for manufacture is largely dependent on the amount of deterioration that has occurred prior to harvesting. Deterioration usually starts shortly after the death of the tree and progresses through the years until the wood elements are once again incorporated in the soil.

Three groups of biological agents—insects, stain, and decay fungi—are responsible for deterioration of woody tissue. Generally, insects and stain fungi initiate the breaking down of newly killed trees, and conditions are favorable for their attack only in the first few years after death (Furniss 1937). Decay fungi complete the deteriorating process over an extended period.

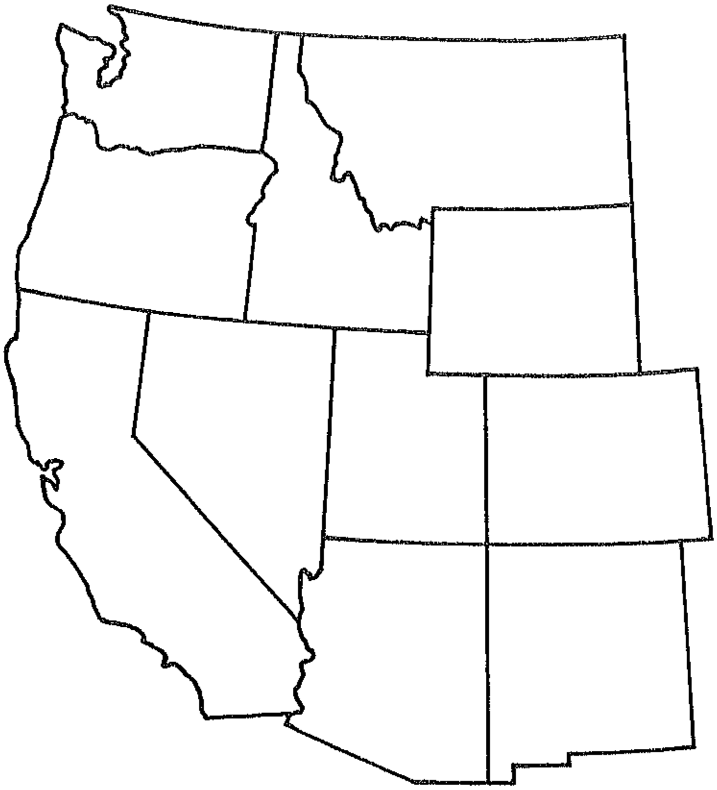

Figure 3.—Factors that increase and decrease the number of dead trees in the western National Forests.

Among those factors that influence the rate of deterioration by the biological agents are the tree characteristics and the environment. Wood characteristics include species, size of tree, amount of sapwood and heartwood, rate of growth, age of tree, and moisture content (Beal and others 1935).

The rate of deterioration is influenced by the rate of moisture loss. Rapid moisture loss prevents attack by insects, stain, and decay fungi; however, slow moisture loss permits attack by these biological agents. The loss of moisture, whether rapid or gradual, causes the dead tree to shrink in size and develop seasoning checks or longitudinal openings in the wood surface. These checks reduce the quantity and quality of solid wood products that can be obtained from dead trees (Keepf 1978). The openings also often serve as focal points for fungal attack, thereby hastening the deterioration.

Some tree species are inherently more durable or more resistant to deterioration than other species. In general, those species with a distinct color differentiation between the heartwood and sapwood are the most durable. In the Northwest, western redcedar (*Thuja plicata* D. Donn) and the other cedars are very durable. Douglas-fir and western larch (*Larix occidentalis* Nutt.) are the next most durable. A general durability classification system developed at the USDA Forest Products Laboratory (Hunt 1941) groups the Northwest softwood species as follows:

Class I	Heartwood very durable CEDARS
Class II	Heartwood durable DOUGLAS-FIR (DENSE)
Class III	Heartwood intermediate in durability DOUGLAS-FIR (UNSELECTED) WESTERN LARCH
Class IV	Heartwood intermediate with classes III and V WESTERN HEMLOCK (*Tsuga heterophylla* Sarg.) PINES SPRUCES (*Picea* spp.)
Class V	Heartwood low in durability FIRS

The sapwood of all species is low in durability (USDA 1935). In the living tree, sapwood contains living cells, and at the time of death, the cell contents become a food source for insects and stain fungi. On the other hand, most of the cells in the heartwood are dead and the cell contents consist of extractive and extraneous material. As a result, old-growth trees of large diameter that have a relatively narrow sapwood band surrounding a large amount of heartwood are more durable than younger, second-growth trees that usually have large sapwood bands and relatively small amounts of heartwood (Wright and Harvey 1967). In addition, trees with wide growth rings are less durable than narrow growth-ringed, slow growing trees (Kimmey and Furniss 1943).

re content of the wood is also a major
rioration Optimum moisture content ranges
fungi growth are somewhat restricted, and
f optimum conditions may be an additional
ion The lower moisture content for opti-
levelopment is about 27 percent, and fungal
s when the moisture content falls to about
oyce 1948). In the coastal area, moisture
ely a limiting factor Wet wood will support
ll or most of the oxygen is displaced by
er, the wood in a standing tree absorbs very
in the first few years after death even in a
Vhere the climate is dry, the moisture con-
s below the limits for decay in the upper
le At high elevations and on some eastern
ration is considerably retarded, and in
-s decay is essentially arrested except at
e tree where ground moisture is available
that fall generally break at or near the
nere moisture from the soil has moved into
created conditions favorable for the growth
i. After falling, such trees may remain
able for some time, especially if they are
tacting the ground, supported by other
debris.

Mountain and Northwest regions possess a
graphical features that have a distinct
ocal environment West of the coastal
ge the temperatures are relatively mild and
ndant, whereas east of this range tem-
more variable and rainfall more moderate.
e conditions alone, in addition to influ-
rcent moisture content, can also affect the
rate. Optimum temperature for wood de-
ranges from 68° to 97° F (20° to 36° C),
num temperatures permitting growth vary
C) to as much as 25° F (16° C) above the
wright and Findlay 1934, Humphrey and

of death and the position of the tree are
affecting the deterioration rate. Trees killed
s that burrow in the cambial layer often
ark earlier than trees killed by other
mentioned earlier, downed trees in contact
d are usually at a higher moisture content,
the growth of decay fungi Standing trees,
and, may dry out rather rapidly and the
e content retards or prevents the growth of
ungi, especially in the upper tree parts.

e Death

oration of dead trees is time related,
necessary for recovering maximum values.
r of tree death is thus an important con-
cting the tree's potential use. Studies
nges in the tree's appearance can be used
e of death reasonably well for the first 5
licators generally used are: needle colora-
tion, twig and small branch retention, large
on, bark retention, top appearance, and
ngal fruiting bodies or sporophores.

Following death, the needles lose their green color and become dark or reddish brown Within 2 years, most of the needles and some of the finer branches have been lost from the tree Larger branches start to break off after 3 to 5 years. The bark is the next part to slough from the tree. After 6 to 8 years, about half of the dead trees have broken tops Fruiting bodies often develop after 5 years Combinations of these indicators can be used to estimate the time of death within narrow limits

Tegethoff and others (1977) used the following criteria to classify dead lodgepole pine in southeastern Idaho·

1-3 years dead· foliage bright orange to straw-colored to gray; some foliage lost.

3-5 years dead no foliage and most of the small twigs that supported the needle fasicles lost

5+ years dead no small twigs and bark peeling.

Cole and Amman (1969) studying lodgepole pine killed by the mountain pine beetle in western Wyoming and eastern Idaho developed these guides

Killed in current year. green foliage, fresh boring frass, eggs or larvae present.

Killed in previous year foliage bright orange to straw-colored.

2 years dead· foliage dull orange and most of foliage retained on tree

3 years dead· foliage dull orange to gray and most of foliage lost from tree.

4 years dead. no foliage and most of the twigs that supported the needle fasicles also lost.

5+ years dead: bark peeling.

Changes in Douglas-fir in western Oregon and Washington have also been reported (Wright and Wright 1954; Wright and Harvey 1967). The 1954 study used the following system

1-3 years dead: no foliage but smallest branches retained on tree. May have many sporophores (*Polyporus volvatus* Pk) small, whitish to buff colored and somewhat globose.

3+ years dead: small branches fallen, examination of wood to determine extent of deterioration necessary.

Indicators used by Wright and Harvey (1967) were·

1 year dead· foliage all present to all gone but red; blue stain and fresh *Polyporus volvatus* conks present.

2-3 years dead: no foliage; 60-90 percent of twigs and small branches (less than 3/4 inch [1.9 cm] in diameter) present; *P. volvatus* conks dried, rudimentary *Fomes pinicola* conks

4-5 years dead: 40-75 percent of twigs and small branches present; 50-90 percent of larger branches (3/4 inch [1.9 cm] and over in diameter) present; some breakage in top one-fourth of crown; *P. volvatus* conks sloughed, *F. pinicola* conks bracket-shaped with reddish margin

6-8 years dead: 0-15 percent of twigs and small branches present; 30-60 percent of large branches present; bark sloughing and cracking in top 25 ft (7.6 m); upper half of about 50 percent of trees broken off; *F. pinicola* conks often very large.

9-10 years dead: 10-50 percent of large branches present; considerable cracking and sloughing in top 50 ft (15.2 m) of unbroken boles; upper two-thirds of 75 percent of trees broken, others have some breakage; *F. pinicola* conks very large and conks of other fungi present.

Guides for western hemlock and western redcedar in Alaska have been reported by Embry (1963). His system is as follows:

<5 years dead. western hemlock, needles nearly gone, small branches 25 percent gone, secondary branches 0-25 percent gone; western redcedar, needles 50-100 percent gone; small branches 25-100 percent gone; secondary branches 0-50 percent gone; primary branches 0-25 percent gone

6-9 years dead; western hemlock, no needles; small branches 50-100 percent gone; secondary branches 25-100 percent gone, primary branches 25-50 percent gone; bark partly gone; stem 0-25 percent gone; *F. pinicola* conks present; western redcedar, no needles, small branches 50-100 percent gone, secondary branches 25-100 percent gone, primary branches 25-100 percent gone; bark 0-25 percent gone; bole 0-25 percent gone.

Case Studies of Tree Deterioration

The deterioration of beetle-killed Englemann spruce (*Picea engelmannii* Parry) and lodgepole pine in the mountains of western Colorado has been reported by Hinds, Hawksworth, and Davidson (1965) and of Engelmann spruce in Utah by Mielke (1950).

Most of the Colorado mortality occurred between 1943 and 1945, and the decay volume was measured at 5-year intervals through 1961. The study results indicated the decay volume of Engelmann spruce averaged about 11 percent of the gross cubic foot volume in the sampling years. Most volume loss was attributed to sapwood rots that were defined as decays that went from the outside of the trunk and progressed inward. Such rots usually started at the base of the tree or in the roots. Moisture content determinations showed that the upper part of the bole was about 20 percent and the lower portions of the stem had moisture contents between 50 and 100 percent. The higher moisture content favored the growth of the decay fungi and the location of the rot increased the possibility of the trees being windthrown. A windthrow trend line for all plots indicated that about 8 percent of the volume had been windthrown 10 years after peak mortality and 28 percent after 20 years. Fallen trees decay rapidly and the rate was about twice as fast for trees in contact with the ground. Infections in the downed trees usually started around drying checks where moisture accumulated. In one study area lodgepole pine accounted for about two-thirds of the trees killed by beetles in 1946. The volume of blue-stained wood and the rate of decay for this species was about the same as for Engelmann spruce in the same area. Windthrow loss was slightly less than for spruce; however, projected windthrow loss indicated about 45 percent of the lodgepole volume would be on the ground in 20 years. Decayed roots were responsible for about 44 percent of the windthrown trees.

Mielke's study (1950) of the beetle-killed Engelmann spruce in Utah showed that, after 25 years, 84 percent of the dead spruce trees of all sizes were still standing. Of those trees that had fallen, a higher percentage were of the smaller size classes. Decay fungi and root and basal rots were responsible for felling 77 percent of the downed trees. The decay rarely extended more than 1 to 2 ft (0.3 to 0.6 m) above ground level. In downed trees decay usually started a few years after they fell, especially if the trees contacted the ground. In trees supported off the ground, decay usually started around seasoning checks where rainwater collected. At high elevations summer rains required for favorable decay conditions occur only occasionally so the rate of deterioration is slow. The moisture content of trees dead for 3 years or longer was less than 22 percent, too low for fungi to grow. On the study area the dead trees dried fairly rapidly, often starting to check while the needles were green. Examination of logs cut from the dead trees indicated 65 percent had a single large check, 15 to 20 percent had two checks, and occasional trees, three checks. About 15 percent of the trees developed numerous small checks but no large ones. Data obtained in this study indicated that beetle-killed spruce in Utah could remain standing for more than 20 years.

The work of Lyon (1977) indicated that lodgepole pine trees, fire-killed in western Montana, have variable rates of attrition depending largely on diameter. The first 2 years after the fire, very few trees were felled but the average annual attrition rate for the next 13 years was 13.4 percent. Snags smaller than 3 inches (7.6 cm) in diameter had an attrition rate of 27.9 percent, trees 3 to 8 inches (7.6 to 20.3 cm) in diameter had a rate of 8.4 percent, and trees larger than 8 inches (20.3 cm) had a sporadic attrition rate. Some of the larger trees would probably stand indefinitely.

Wagner and Offord (1972) studied the deterioration of logging slash in northern California. They indicated that the major factors influencing the rapidity of the slash breakdown were climatic (precipitation, temperature, insolation, and soil moisture) and biologic (tree species and decay fungi). Temperature and moisture records from near the study areas indicated high summer temperatures and low wood moisture contents limited the growth and spread of common decay fungi. An interval of 30 years was needed to reduce the fire hazard from extreme to a rating comparable to that of the prelogged condition; 43 percent of the original slash volume remained after 29 years.

Another California study (Kimmey 1955) reported on the deterioration of fire-killed trees of species such as ponderosa pine, Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.), sugar pine (*Pinus lambertiana* Dougl.), Douglas-fir, and white fir (*Abies concolor* [Gord. and Glend.] Lindl.). Fungi and insects were the principal deterioration agents. Deterioration started the first year after death with blue stain developing under the bark. Additional staining and incipient decay occurred in the sapwood during the second year, and after 3 years the sapwood was no longer salvable; only the larger trees had sufficient sound wood to justify salvage. Although the white fir did not stain extensively, it was severely decayed by the end of the second year. After 3 or 4 years even large logs of this species were beyond salvage. Ponderosa and Jeffrey pines, both with thick sapwood, had slower deterioration rates than fir. However, few logs would be salvageable after 5 years. Sugar pine had a thin sapwood

and a relatively durable heartwood. Large logs of this species could be salvaged 10 years after the fire. The heartwood of Douglas-fir decayed slowly in old trees so that large logs could probably be used 15 to 20 years after death Other study results indicate that heartwood deterioration was faster in trees with wide growth rings, and younger trees deteriorated faster than older trees under the same conditions

The rate of deterioration of beetle-killed Pacific silver fir (*Abies amabilis* Forbes) was studied by land managers in the Northwest (Wright and others 1956). The study showed that this species deteriorates at a rate of 5 percent or more of the total volume up to 4 years after death However, log scale deductions for rot were 30, 39, and 54 percent for logs from trees dead 2, 3, and 4 years, respectively. Observations indicated that younger trees of smaller diameter would probably deteriorate more rapidly than older, larger trees because of the greater proportion of sapwood

A virgin timber blowdown area on the Olympic Peninsula in Washington was the site of a long-term study (Boyce 1929, Buchanan and Englerth 1940) Observations were made annually for the first 4 years following the catastrophe, and at 5, 10, and 15 years detailed examinations were made of five tree species—Douglas-fir, western redcedar, silver fir, sitka spruce (*Picea sitchensis* [Bong] Carr.), and western hemlock For the first 3 years ambrosia beetles and blue stain attacked and degraded the sapwood of all species. From the fourth year on decay organisms became increasingly important so that 5 years after the blowdown virtually all the sapwood of all species had been destroyed, as well as considerable heartwood of the less durable species, silver fir, western hemlock, and Sitka spruce (table 2) Western hemlock and silver fir, the two species with the greatest percentage of sapwood and the least durable heartwood, decayed most rapidly These species were made worthless after about 8 years. There was little difference between the heartwood and sapwood of Sitka spruce, and all sound wood of this species was destroyed in 15 years The sapwood of Douglas-fir deteriorated rapidly but the heartwood was much more durable. Trees 30 inches (76 2 cm) and larger in diameter had a considerable volume of usable heartwood after 15 years. Western redcedar was the most durable species, having lost only its sapwood in the study period

Table 2.—The percentage of board foot and cubic foot volume loss for five Olympic Peninsula tree species after 5 years (source: Boyce 1929)

Species	Percent of loss	
	Bd.ft	*Ft³*
Western redcedar	26 5	22.0
Douglas-fir	34.5	34 2
Sitka spruce	46 3	41.7
Silver fir	73 5	55.8
Western hemlock	91 9	68.4

Defect

The occurrence and type of defect can have a profound effect on the use of dead trees Spiral checks and splits may prevent the use of these logs for lumber manufacture or severely reduce grade recovery Rot and fire scars affect the pulp chip yield. Drying of the wood and the development of defects start shortly after the tree dies, and defect severity increases with time Table 3 shows the frequency of defect occurrence in samples of green and dead lodgepole and western white pine trees selected for sawmilling studies The lodgepole pine trees (1,568) were taken from south-central Montana and the western white pine trees from north-central Idaho. In general the data show that breaks, checks, spiral checks, splits, and rots occur more frequently in dead trees than in green trees.

Characteristics of Deadwood

The processing and use of many species depends to a large extent on the inherent physical and mechanical properties as well as the chemical constituents of the wood. For dead tree wood, an understanding of these characteristics and knowledge of the differences between dead and green tree wood are essential for its utilization Although no exhaustive evaluation of dead tree wood has been made, the following information has been obtained for lodgepole and western white pine. It is believed that the conclusions based on this information are generally applicable to wood obtained from dead trees of other western softwood species

The physical characteristics of dead tree wood are only slightly affected by long-term exposure in the forest. After the bark sloughs from the tree, the exposed wood surface gradually assumes the gray color characteristic of unprotected wood. This change in color is due to oxidation, leaching of extractives, and deposition of dust and dirt. These same factors are responsible for the loss of the wood's normal odor and taste.

When dead tree logs are milled, the wood does not have the usual luster associated with freshly cut green wood. This difference may be due to the dead log's lower moisture content, which results in a greater tearing of the fibers on the surface.

The weight of dead wood is also affected by its moisture content, which decreases with time. Lowery and Hearst (1978) reported average moisture content of 16.5 and 23.7 percent for lodgepole and western white pine lumber, respectively, cut from dead tree logs. The results of specific gravity determination on the same sample material indicated no significant difference from the specific gravity of green wood. The specific gravity determinations were based on green volume and ovendry weight.

A few of the mechanical characteristics have also been studied. Gernert and others (1980) reported on the percent shrinkage and specific gravity for three types of western white pine wood. They found no significant differences between the shrinkage characteristics and specific gravity for live, dead down, and dead standing western white pine trees. Lowery and Pellerin (1982),

—*Distribution of scaling defects by number and percentage for lodgepole pine in Montana and white pine from north Idaho (source Unpublished data USDA Forest Service, Region 1, Missoula, Mont)*

	Belgrade lodgepole pine						Dillon lodgepole pine				Western white pine					
	Green		Red needled		Dead, down and standing		Green		Dead		Green		› 90% bark retained		‹ 90% bark retained	
	14	(4 0)[2]	6	(3 0)	9	(1 9)	4	(1 8)	8	(2 0)	84	(34 5)	95	(23 1)	75	(14 7)
	159	(45 2)	75	(37 1)	49	(10 2)	74	(33 3)	41	(10 0)	8	(3 3)	—		4	(0 8)
ιke	1	(0 3)	—		—		1	(0 5)	—		5	(2 1)	2	(0 5)	1	(0 2)
	3	(0 9)	56	(27 6)	326	(68 1)	6	(2 7)	255	(62 2)	19	(7 8)	203	(49 3)	253	(49.3)
necks	—		9	(4 5)	—		—		22	(5 4)	—		—		4	(0 8)
	1	(0 3)	3	(1 5)	—		—		—		—		1	(0 2)	2	(0 4)
	44	(12 5)	18	(8 9)	56	(11 7)	54	(24.2)	29	(7 1)	65	(26 8)	54	(13 1)	100	(19 5)
	8	(2 3)	1	(0 5)	7	(1 5)	74	(33 3)	47	(11 3)	53	(21 8)	54	(13 1)	73	(14 3)
am	—		—		—		5	(2 3)	5	(1 2)	6	(2 5)	2	(0 5)	—	
imb	—		3	(1 5)	—		—		—		1	(0.4)	1	(0 2)	—	
	80	(22 6)	21	(10 4)	26	(5 4)	—		2	(0 5)	2	(0 8)	—		—	
ell	12	(3 4)	3	(1 5)	2	(0 4)	—		—		—		—		—	
	30	(8 5)	2	(1 0)	4	(0 8)	3	(1.4)	1	(0 3)	—		—		—	
	—		5	(2 5)	—		—		—		—		—		—	
	—		—		—		1	(0.5)	—		—		—		—	
fects.	352	(100 0)	202	(100.0)	479	(100 0)	222	(100 0)	410	(100 0)	243	(100 0)	412	(100 0)	512	(100 0)
;	472				468		277		351		68		54		54	

not include logs lost due to breakage
bers in parentheses are percentages

I the destructive and nondestructive bending h properties of lodgepole and western white pine ·ion lumber. Again, the data indicated that there significant difference between the modulus of ty and the modulus of rupture of green wood and ɔod of these species.

and others (1979) studied the chemical charac- ɜ of dead and green lodgepole and western white eartwood and sapwood from green, dead down, ɜd standing trees were analyzed. The average per- ɘ of cell wall components, holocellulose, alpha ɛe, hemicellulose, and Klasen lignin, were very There was no significant difference between the nd dead tree samples nor between the heart- nd sapwood samples. These researchers also ɔ the combustion characteristics of the same ʳpes, as did Kelsey and others (1979). The higher values for the samples studied were essentially ɪe. The major discrepancy between the green nd deadwood data was in the percent ash content ead trees had greater absolute amounts of ash ɪ the green trees.

ɘ studies indicate that deadwood characteristics ɪiffer significantly from green wood. In addition, ɔus insurmountable difficulties were encountered ŋg particle board from deadwood flakes and urea- ol-formaldehyde adhesives (Mueller 1959; Maloney ers 1976). However, other investigations indicate machining, milling, or chipping of dead tree ıquires more energy than the processing of green owery and others 1977; Maloney and others 1976).

SELLING METHODS

The usual method of selling timber from Federal Government land applies a set price per thousand board feet to the log scale volume of each species removed. When the value of the logs is relatively high, or when the various species have different values, this method has proved equitable to both buyer and seller. However, when timber values are low and the cost of preparing and administering the sale exceeds the potential return, other methods may be used.

Combes (1978) discusses some of the problems encountered in appraising and selling dead timber and presents methods for overcoming these problems. According to Combes, more mill cost studies are needed to develop the appraisal method that would best be applicable for all dead timber situations.

Some of the alternative sales methods used with dead timber are lump sum, piece rate, per acre, per ton, or per cord. In a lump sum sale, a particular quantity of timber is sold for a price set prior to harvesting. In some instances, dead trees may also be sold by the piece. A sales procedure developed in the Pacific Northwest region has been termed PAM (per acre material) (Hamilton and others 1975), where the purchaser pays a fixed amount for the material on each acre. This system was devised initially to sell postlogging residue, but it can also be used to sell dead timber. The purpose of PAM is to encourage the buyer to remove the low-valued material on a logged area rather than leave it for disposal. The principal advantage of PAM is that sale costs are minimal.

Green and dead timber have also been sold on a weight, cubic volume, or cord basis When mixed stands of green and dead are sold by weight, the weight of each type is prorated to obtain an average that can be used for the entire sale The weight of truckloads of dead tree logs typically ranges from about 31,000 to 43,000 lb (14 091 to 19 545 kg). Although the present practice is not to scale the loads of dead trees as sawlogs, a few such loads have been scaled in the past as shown in table 4 These data also illustrate the effect on lumber recovery of defects present in dead tree logs, the difference between gross and net log scales Many dead tree logs are chipped for pulp rather than sawed into lumber, in which case only two defects, rot and fire scar or charcoal, are considered important. The cull for these defects is usually less than 10 percent

When dead timber is to be converted into pulp chips, the cubic volume measurement may be used. The relationship between weight and cubic volume is established by first weighing the truckload of logs and then measuring the individual logs in sample loads (table 5). The cubic volume in feet can be computed using Smalian's equation

$$\text{Volume} = 0.002727\,(D_1^2 + D_2^2)L$$

where·

volume is in cubic feet

D_1 and D_2 are end diameters in inches

L is length in feet

About 1 percent of the load volumes was considered cull because of rot.

In some instances the cubic volume has been converted to cords using a conversion factor of 86 6 ft^3 (2 45 m^3) per cord. Pulp and paper plants frequently use this measurement.

Table 4 —Weight, scale, and number for typical loads of dead lodgepole pine logs (source Targhee National Forest, St Anthony, Idaho)

Load	Load weight	Gross scale	Net scale	No. of logs
	Lb	*M bd. ft*	*M bd. ft.*	
1	36,440	4 29	0 80	77
2	40,380	5.30	1 22	63
3	38,260	5 12	0 97	64
4	41,400	5 55	1 16	80
Average	39,120 (17 782 kg)	5.07 (1 46m³)	1 04 (0 30m³)	71

Table 5 —Weight, cubic foot volume, and number for typical loads of dead lodgepole pine logs (source Lolo National Forest, Missoula, Mont)

Load No.	Weight	Volume	Weight	No. of pieces
	Lb	*Ft³*	*Lb/ft³*	
1	38,160	1,020	37 4	85
2	44,440	1,199	37.1	84
3	39,120	1,136	34.4	69
Average	40,573 (18 442 kg)	1,118 (31.64 m³)	36.3 (582 23 kg/m³)	79

UTILIZATION OF DEAD TREES

The preceding sections have indicated, on the basis of wood characteristics, that there are no restrictions limiting the use of dead tree wood However, the appearance and defects of dead trees and logs often inhibit the use of this material for specific purposes. Lower quality or reduced quantity may be the principal deterrents Various possible uses are presented in the following sections.

Lumber

One of the highest value products most commonly associated with trees is lumber (fig. 4). A number of studies have sought to determine the quantity and quality of material obtained from dead trees of different species, and to compare these values with determinations obtained from matched samples of green tree logs. All the studies indicate that dead trees can be used for lumber production. However, the lumber recovered from such trees is lower in quantity, quality, and value (with a few exceptions) than lumber made from comparable green trees. A greater loss in volume due to breakage is incurred in the felling and handling of dead trees and logs. Decay and borer damage in the sapwood and soil embedded in the outer wood of barkless trees may require heavy slabbing and greater cull board production.

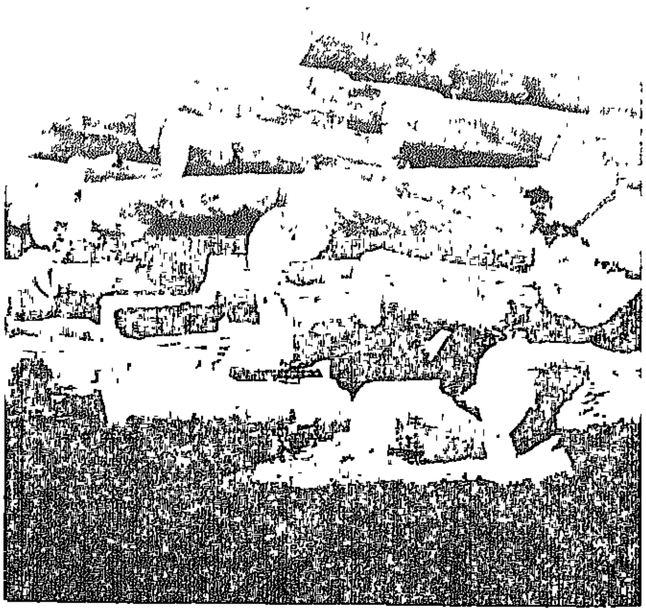

Figure 4.—Decks of dead tree logs before being processed into dimension lumber and pulp chips.

The studies also show that if lumber quality is to be maintained, prompt salvage of dead trees, before complete foliage loss, is necessary. Usually the best and highest valued boards are cut from the clear wood immediately under the bark This wood is also most readily attacked by decay and stain fungi and wood-boring insects Lumber made from the inner part of the log often contains knots or other degrading features. As long as the bark remains intact on the dead trees, lumber quality decreases slowly, but after about 5 years the bark sloughs, deep checks develop, and the rate of quality decline increases. Quality and quantity have a direct effect on the value of lumber made from dead tree logs. As the time since death lengthens, the value of the lumber produced from the dead trees decreases.

A discussion of the study results by species follows.

Lodgepole Pine

The results of lumber grade-yield studies for this species have been reported by Carr (1978)[1] and Dobie and Wright (1978b). Carr summarized studies made on three National Forests in Montana—Bitterroot, Gallatin, and Beaverhead. The Bitterroot study used green and dead trees obtained from a decadent, old-growth stand. The dead component included a wide variety of natural mortality quality classes, from the recently dead to downed trees Both dimension and boards were cut from the study logs.

In addition to the green, control logs, the Gallatin study included green-needled trees that showed signs of medium to heavy bark beetle infestation; red-needled trees, dead less than 3 years; and trees dead longer than 3 years. Only 1-inch (2.5-cm) thick lumber was produced in this study.

The Beaverhead study trees were either green or dead, and the dead included a few red-needled trees and others taken from the ground. Primarily, dimension lumber was produced from the study logs. All the study logs had a minimum small end diameter of 5.6 inches (14.2 cm), a minimum length of 8 ft (2.4 m), and were at least one-third sound. A summary of the study results is shown in table 6.

Table 6.—Comparison of grade-yield studies using green and dead lodgepole pine logs obtained from three National Forests (source: Carr, W R. 1978)

Study	Percent dimension lumber	Value per M bd.ft. lumber tally	Percent lumber recovery	Value per M net log scale
		Dollars		*Dollars*
Bitterroot				
Live	41	221.99	150	332.98
Dead	60	150.41	134	201.55
Gallatin				
Live	0	261.53	121	316.45
Dead	0	199.81	114	227.78
Beaverhead				
Live	89	177.53	172	305.35
Dead	91	161.82	150	242.73

The summary shows that dead trees have value when used in lumber production The quality of lumber made from green and dead trees is reflected in the value per thousand board feet (M bd.ft) lumber tally Obviously, a lower quality of lumber is produced from the dead tree logs The differences between values ranged from $15.71 per M bd ft for the Beaverhead study to $71 58 per M bd.ft. for the Bitterroot study. The summary also shows that the highest values were obtained when lumber 1 inch thick (2 5 cm) was produced (Gallatin study). The percent lumber recovery indicates a smaller quantity of lumber was made from the dead tree logs than from the green tree logs. Just as the increased number of kerfs required to produce lumber 1 inch thick (2.5 cm) reduced the percent lumber recovery in the Gallatin study; so also, the increased number of defects in the dead logs reduced the percent lumber recovery in all the studies. The value per thousand board feet net log scale indicates both the quality and quantity of lumber produced from the green and dead logs

Another mill-scale study (Plank 1979) used 267 live and dead lodgepole pine in Wyoming—120 live and 147, or about 55 percent, dead For the live trees the lumber recovery was graded 47 percent Standard or Better, 17 percent Utility, and 8 percent Economy. For the dead trees only 24 percent was graded Standard or Better, 37 percent Utility, and 13 percent Economy. The lumber recovery from the two tree types, based on gross log cubic volume, was essentially the same—32 and 31 percent for the live and dead samples, respectively.

In a Canadian lodgepole pine study, Dobie and Wright (1978b) used four categories of trees; (1) green; (2) red-needled, some dead more than 2 years; (3) gray with tight bark, probably dead more than 4 years, and (4) gray with loose bark, dead longer than the preceding group. The study results were essentially the same as Carr's. A smaller quantity and lower quality of material was produced from the dead trees than from the green trees. Also, the study indicated that beetle-attacked trees should be harvested prior to foliage loss, if possible. The lowest values and quantities were obtained from those trees dead the longest time.

True Firs

Lumber grade-yield studies using species of the true firs have been made in the United States and Canada (Woodfin 1976; Snellgrove and Fahey 1977; Dobie and Wright 1978a). White fir and grand fir (*Abies grandis* [Dougl.] Lindl.) trees in Oregon killed by the tussock moth were milled after about 2 years, along with a matched sample of green logs. The bark on the dead trees, defoliated by the insect larvae, had begun to loosen. Average diameter at breast height (d.b.h.) for the green trees was 27 inches (68.6 cm) and for the dead trees 24 inches (61.0 cm). About 98 percent of the lumber produced was dimension, 2 inches (5.0 cm) thick, and the remainder was 1 inch (2.5 cm).

[1]Carr, W. R. 1978. Comparison of lodgepole pine lumber recovery from live and dead timber. USDA For. Serv office rep , Region 1, Missoula, Mont

The quality and quantity of lumber recovered from the dead trees were affected by the time since death. According to Woodfin (1976), the green trees had a value of $59 per hundred cubic feet and the dead trees $43 per hundred cubic feet The quality loss was about 27 percent. Also, 51 percent of the dead tree lumber was No 3 Common, Standard or Better, and 49 percent was No 4 Common, Utility, and Economy. For the green trees, these percentages were 61 and 34, respectively. The dead trees had a scaling defect of 41 percent and a cubic lumber recovery of 28 percent, as opposed to a scaling defect of 36 percent and a cubic lumber recovery of 32 percent for the green trees.

Alpine fir (*Abies lasiocarpa* [Hook] Nutt) was the species used in the Canadian study (Dobie and Wright 1978a) The research objective was to evaluate a system used to separate dead trees into two quality classes class 1, those with unbroken tops or with tops broken in the stem at a point smaller than 4 inches (10.2 cm) diameter; and class 2, snags with tops broken in the stem at a point larger than 4 inches (10 2 cm) diameter. A total of 100 trees, representing the complete range of merchantable d.b h , were selected for each quality class. Approximately 99 percent of the lumber produced was dimension, 2 inches (5 0 cm) thick

This study indicated that the classification system in general distinguished lumber values The trees in quality class 1 had greater value and produced more lumber than trees in quality class 2. The average value per M bd.ft of class 1 trees was $152 70, and the average value per M bd ft for class 2 trees was $143 40 A comparison of the average percent lumber grade yields for the two quality classes is:

	No. 2 and Better	No. 3	Economy
Class 1	30	46	24
Class 2	20	52	28

The average lumber recovery factor (LRF) or board feet of dry, surfaced lumber per cubic foot for class 1 was 5.3, and for class 2 was 3.8.

Western White Pine

Two studies in northern Idaho sought to determine the value of dead western white pine trees (Snellgrove and Fahey 1977; Snellgrove and Cahill 1980; and Carr 1979[2]).

[2]Carr, W R 1979 Comparison of white pine lumber recovery from live and dead timber USDA For Serv office rep., Region 1, Missoula, Mont

The Snellgrove and Cahill report contains a detailed discussion of the characteristics, problems, and product recovery associated with one dead white pine milling study. The four tree classes used in the study were:

- Live: living green trees
- Class I: dead trees with some brown needle retention
- Class II: dead trees with no needles and 90 percent or more of the bark retained on the tree
- Class III: dead trees with no needles and less than 90 percent of the bark retained on the merchantable portion.

The average d.b h. of the classes ranged from 20 to 23 inches (50 8 to 58.4 cm). All logs were processed into 1- and 1 1/4-inch (2 5 and 3.2 cm) lumber.

The study results showed that the trees dead the longest time (class III) had the greatest loss of usable wood. The percent loss in volume due to felling, handling, and transporting to and around the mill was as follows.

Determination class	Percent loss
Live	3.5
I	4.6
II	7.7
III	7.9

The tops of the older dead trees have a lower ability to absorb shock and tend to shatter when the trees fall In addition, smaller amounts, lower grades, and narrower boards are obtained from dead trees. Table 7 is a summary of value, grade yield, and 6-inch (15.2-cm) and narrower board recovery for the different study classes.

The second western white pine study (Carr 1979) had three classes of trees: (1) live, (2) probably dead less than 5 years, 90 percent or more of the bark retained on the tree; and (3) probably dead more than 5 years, less than 90 percent of the bark retained on the tree. All logs were at least one-third sound and were cut into 1- and 2-inch (2 5- and 5.0-cm) lumber. The results, summarized in table 8, showed that the older dead trees had a greater percentage of defective material (gross versus net log scale), and, based on net log scale, a greater percentage of lumber was recovered from these logs. However, the value per M bd.ft. was less and the associated lumber quality was lower. Table 8 shows the summary of log scaling data and lumber grade recoveries for three classes of western white pine trees.

Table 7 —Summary of value, grade yield, and 6 inch and narrower board recovery for different classes of western white pine trees (source. Snellgrove, T. A , and J M. Cahill 1980)

Deterioration class	Cubic defect	Average value per M bd.ft.	Average value per C ft³	Boards 6 inches and narrower	Lumber grade recovery: Select and clear	Nos. 1, 2, 3 shop	Nos. 1, 2 common	No. 3 common	No. 4 common	No. 5 common
	Percent	*Dollars*	*Dollars*	*Percent*	*Percent*					
Live	9 4	204	104	20	5.12	8 87	26 59	47.16	11.48	0.78
Class I	12 8	160	79	24	1 56	3.10	15 56	54.20	24.16	1.42
Class II	21.2	122	57	27	1.05	5.42	6 95	39 23	42 68	4.67
Class III	24.8	101	44	35	0.31	1.23	1 72	19.46	62.03	15 26

Table 8 —Summary of log scaling data and lumber grade recoveries for three classes of western white pine (source· Carr, W R 1979)

Tree class	Log scale Gross	Log scale Net	Lumber recovery	Percent of net scale	Value per M bd.ft.	No. 3 clear and better	Shop	5C and better	Standard and better	Utility and economy
	— Board feet —		M bd ft	Percent	Dollars	— — — — — — — — Percent	— — —	— — —	— — —	— — —
Live	51,450	41,900	54,350	129 7	283 95	13 7	9 8	61 4	12 9	2 2
> 90% bark	40,330	18,420	37,469	204.4	213 73	3.0	5 0	67 8	17 9	6 2
<90% bark	42,910	4,980	41,682	837.0	151 54	0.4	0 4	14 7	36 3	48 2

Ponderosa Pine

Lumber recovery from second-growth ponderosa pine trees killed by mountain pine beetle in eastern Oregon has been reported by Fahey (1980). Included in the board mill study were 40 trees in each of five categories—green, and dead 1, 2, 3, or 4 years; and 30 trees dead either 3 or 4 years were processed in the stud mill.

Trees cut for boards had a major loss in value within 1 year with blue stain being the most important loss factor. The recovery of 2 Common and Better lumber decreased from approximately 40 percent for the green trees to about 3 percent for trees dead 1 year or longer. The volume recovery at the stud mill was slightly greater than at the board mill.

As in other species studies, this study also indicated that tree and log breakage increased with time since death.

Engelmann Spruce

Cahill (1980) compared the lumber recovery from green and dead Engelmann spruce trees. The results of this grade-yield study closely conform to results of similar studies of other species. The dead tree logs had a greater percent overrun, a lower average lumber value, a greater volume of residual material, and a smaller volume of sawdust. Table 9 is a summary of the study results.

Pulp and Paper

The deterioration of dead timber may progress to the point that salvage for lumber manufacture or use in the round is no longer practical. However, enough sound wood may still be present to justify its removal from the forest for use by the pulp and paper or particle board industries. The suitability of insect-killed timber for these uses has been studied by several researchers, and the pulp and paper industry has gained some experience in using this material when sawmill generated chips have been in short supply (McMichael 1975).

The processing of live, dead down, and dead standing trees of four Rocky Mountain species—lodgepole pine, Engelmann spruce, western larch, and Douglas-fir—has been reported on by Lowery and others (1977) Bolts of each wood type and species were processed through a chipper, and the chip quality and energy required to chip the wood were measured. The percent moisture content of the dead tree bolts was considerably less than for the green tree bolts; this factor was probably responsible for the 30 percent more energy that was required to chip the dead tree bolts than was needed for the green tree bolts The overall chip quality from all the wood types was good; however, a slightly greater percentage of fines was obtained from the dead tree bolts. No difficulty was encountered in separating the tree bark from the chips. Another section of this report is concerned with the experimental pulping of sound lodgepole pine trees dead for at least 15 years. The tests indicate that pulp made from such material should be suitable for a variety of paper and board products.

This testing confirmed work done earlier by McGovern (1951) with the same species. McGovern's research on several types of green and insect-killed lodgepole pine evaluated physical and chemical tests made on ground wood, sulfite, and sulfate pulping. The deadwood differed little in weight per cord and in density from the green wood, although the deadwood was lower in percent moisture content. The insect-killed wood contained considerable incipient decay Chemical composition of the two wood types was about the same; however, the deadwood had lower contents of holocellulose and alpha cellulose.

Sulfate pulping tests made on green and sound deadwood had similar pulping characteristics and gave nearly the same pulp yields and pulp strengths. Deadwood with about 28 percent advanced decay showed a slight tendency to pulp more rapidly and to give lower permanganate numbers, lower pulp yields, and lower

Table 9.—Comparison of results for a mill-scale study that used live and dead Engelmann spruce (source· Cahill 1980)

Type	Log scale Gross	Log scale Net	Lumber tally	Volume Log	Volume Lumber	Volume Sawdust	Volume Residual
	— — — — — — Board feet	— — — — — —		— — — — — — — — — Ft^3 (m^3)	— — —	— — —	— — —
Dead	74,065	34,835	89,834	13,982 (395.69)	6,462 (182.87)	850 (24.06)	6,670 (188.76)
Live	14,850	14,185	21,476	2,748 (77.77)	1,547 (43.78)	206 (5.83)	994 (28.13)

pulp strengths The difference between the green and decayed dead pulps was 5 percent in yield and 10 percent in pulp strength

Sulfite pulping tests, using green and deadwood, yielded pulps containing large amounts of dark fiber bundles that could be bleached Again, the deadwood showed a tendency to pulp more rapidly and gave a slightly lower yield Both pulps had ether solubility values that indicated a potential for pitch problems.

The ground wood pulping tests showed that pulps of good color and strength could be made from both green and dead lodgepole pine with moderate energy consumptions Under comparable grinding conditions, the green wood pulps were better.

In contrast with the relatively long usability of the Northern Rocky Mountain species, trees in the Pacific Northwest have a relatively short usable life After 2 years the sapwood of beetle-killed Douglas-fir was no longer suitable for lumber, but after 3 years some recovery of the sapwood for pulp might be possible (Wright and Wright 1954)

Looper-killed western hemlock on Victoria Island, B C, had deteriorated beyond recovery by the seventh year after death (Engelhart 1957). The deterioration of Pacific silver fir was also fairly rapid. Pulping tests made using beetle-killed fir trees dead more than 2 years showed a decreased yield and impaired pulp strength (Wright and others 1956). After this fir was killed by the balsam woolly aphid, tests showed pulp quality decreased rapidly with increased time after death until an acceptable bleached pulp could not be produced if trees dead for 3 to 5 years were the major wood supply (Shea 1960)

Posts and Poles

Because of their size, straightness, minimum taper, and ease of preservation, green lodgepole pine trees have been preferred for fenceposts, corral rails, and utility poles. These same products when made from dead trees would have a lower moisture content, an advantage that would eliminate a long air-seasoning period, thus reducing the need for a large inventory. This same characteristic indicates lighter weight, hence larger loads and easier treatment.

Post and corral rail specifications are usually developed by the individual treating plants and depend, to a large extent, on local conditions and practices. Appearance is often a major consideration. Pole specifications are published by the American National Standards Institute (ANSI) (1972), and although these specifications do not require the use of living trees, the occurrence and placement of defects may eliminate the use of some dead trees for poles. The preservative treatment of posts and poles is discussed separately.

Posts

Lowery and Host (1979) report on the preservative treatment of posts and poles made from dead lodgepole pine trees. Two treating methods, cold soak or steeping and pressure treatment, were used to treat fenceposts from trees dead for at least 4 years. A total of 85 posts—36 small, 36 large, and 13 control—were used in the steeping study The peeled, pointed, and capped posts were placed upright in a series of tanks filled 30 inches (76.2 cm) with a 5 percent solution of pentachlorophenol in a light crude oil (fig. 5). Three large posts, three small posts, and one control post, selected at random, were removed from the tanks at 30-minute intervals. Six hours was the longest soak period used

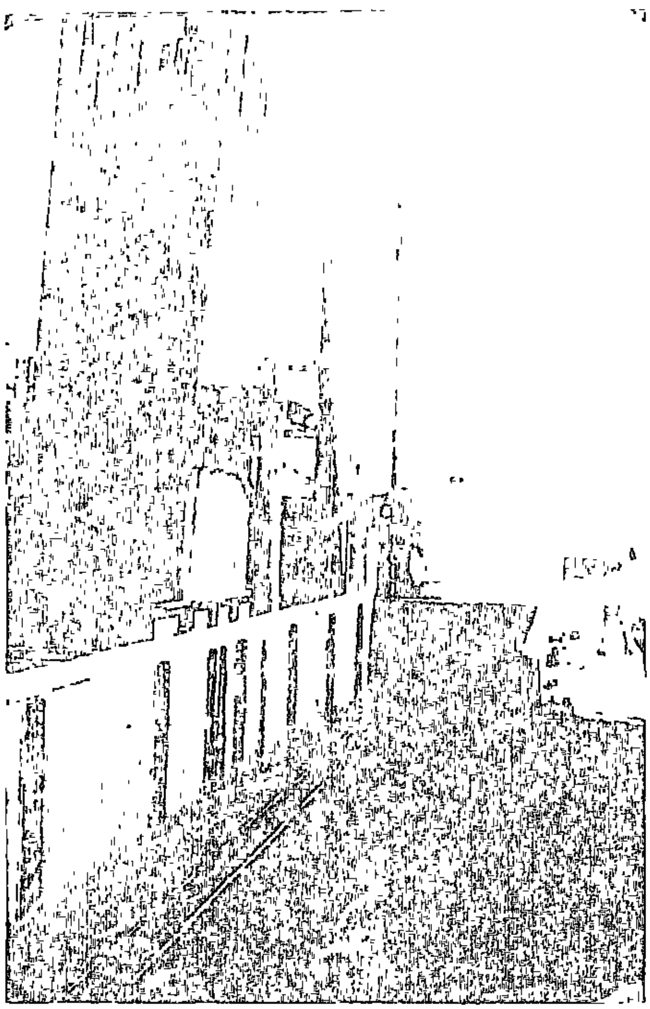

Figure 5.—Lodgepole pine poles are bath-treated with a preservative.

The study results indicated that none of the treatments gave the minimum retention required by the American Wood Preserver's Association (AWPA) standard (1972) of 0.30 lb lb/ft^3 (4.81 kg/m^3). Also, there was no consistent relation between the length of treating time, the depth of preservative penetration, and the pounds per cubic foot preservative retention.

In the pressure treatment phase of the study, 39 posts from dead lodgepole pine trees were used. An unheated water solution 1.50 to 1.75 percent of fluorochrome arsenate phenol, type B (Osmosalts), was the preservative used and the pressure periods were 15, 30, or 45 minutes (fig. 6). After treatment, all the posts had retentions exceeding the specification requirement.

Figure 6.—Fenceposts made from dead lodgepole pines undergo treatment in a pressure cylinder.

Poles

A recent survey of lodgepole pine trees in southeastern Idaho indicated that many of the dead trees were suitable for power poles (Tegethoff and others 1977). Of 217 pole-size trees on 46 plots, 165 were dead; about 38 percent (63) of the dead trees yielded poles that satisfied the ANSI pole standards. The most commonly occurring defect was basal decay; and for many of the dead tree poles this defect had to be eliminated by longbutting

The preservative treatment of poles made from dead lodgepole pine trees has been reported by Lowery and Host (1979). Thirty poles that were 20, 25, or 30 ft long (6.1, 7.6, or 9.1 m) were butt treated. Six treating schedules, three hot-and-cold bath and three cold soak, were used. The results showed that only one of the poles had less than the minimum required retention of 0.75 inch (1.90 cm), and except for those poles given a 4-hour cold soak, all the poles met the 85 percent sapwood penetration requirement. All the poles treated by the hot-and-cold bath exceeded the preservative retention requirement, AWPA Standard A-5 1969, but none of the poles treated by the cold soak method attained the required retention.

Particle Board

In cooperation with the USDA Forest Service's western Experiment Stations, Washington State University's College of Engineering studied the suitability of using dead lodgepole pine and western white pine trees for particle board manufacture. This investigative effort examined the processing of the wood by the several types of available particle generating equipment; determined the quality, quantity, and uniformity of the resulting particles, and evaluated a variety of composition boards produced from the particles (Maloney and others 1976) A supplementary study compared the economics of producing composition board using deadwood particles as opposed to the conventional green wood furnish (Maloney 1981).

Green and dead standing trees of both species and dead down trees of lodgepole pine were included in the test material Particles were made by hammermilling, drum and ring flaking, and atmospheric and pressurized attrition milling. Evaluation criteria included energy required to make an ovendry ton of chips, amount of fines, bulk density, and slenderness ratio The energy requirements in kilowatt-hour per ovendry ton (metric ton) were as follows.

Method	kWh/ton (kWh/t)
Drum flaking	12 (13.2)
Ring flaking	35 (38 6)
Hammermilling	69 (76 1)
Atmospheric attrition milling	101 (111) plus pressurized steam
Pressurized attrition milling	523 (577) plus 450 kWh (496) in processing steam

The amount of fines generated was about the same (4 to 5 percent) for hammermilling and the two types of flaking. For the hammermilled and drum flaked, more fines were created with the dryer material, regardless of species. With the ring flaked, the green material produced the greater amount of fines.

Bulk density is an important factor in determining plant size and equipment. The hammermilled material was the most compact at 10.7 lb/ft^3 (171 kg/m^3). The flakes were intermediate at 6 5 lb/ft^3 (104 kg/m^3) for the ring flakes and 5 lb/ft^3 (80 kg/m^3) for the drum flakes. The two fiber furnishes were about the same, 1 lb/ft^3 (16 kg/m^3). Increasing slenderness tends to enhance bending strength and stiffness but also tends to decrease internal bond strength. The length to thickness or slenderness ratios were 50 for the drum-flaked particles, 22.8 for the ring-flaked particles, and 8.4 for the hammermilled particles. The attrition milled fiber was not measured but probably would be about the same as that of the drum flakes.

Two groups of composition boards were prepared from the various particles. The first group determined the compatibility of the particles with the commonly used urea-formaldehyde and phenol-formaldehyde resin adhesives using these criteria: modulus of rupture, modulus of elasticity, water-soak test, and linear expansion. The second group of boards was typical of those produced commercially for underlayment, furniture core, door core, structural flakeboard, and hardboard.

The major conclusion derived from study of the first group of boards was that the dead classes of white pine and lodgepole pine could be used for various types of

composition board. Of the particles studied, hammer-milled, ring-cut, and atmospheric- and pressure-refined fiber appeared to be best. Structural flakeboards of drum-cut flakes had low internal bond.

Standing dead white pine and lodgepole pine retained those properties important for use in composition board products, even after standing dead for many years. Deterioration such as deep checking, sapstain, and pockets of decay that prevent using these trees for lumber and plywood, also had an adverse effect on their use for particle board

The typical commercial boards made from the dead class material showed excellent overall properties. All boards had good properties except for excessive linear expansion in lodgepole pine boards and the internal bond in structural flakeboard. All other boards were of superior quality.

An economic comparison study (Maloney 1981) indicated that particle board plants using dead tree stock would require the same major equipment as plants operating conventionally. Using the given condition of starting with roundwood delivered to the plant, particle preparation equipment would be essentially the same. Knives used to prepare the particles from dead trees would probably be subjected to more wear and require more maintenance than those for bolts from green trees. Additional screening capacity might also be needed for the deadwood furnish to segregate the fines. The lower percent moisture content of the dead tree wood would reduce the need for dryer capacity and also reduce the cost of drying. In addition, more waste usable as fuel would be created from the deadwood. The principal conclusion from this study was that comparable composition boards would have similar manufacturing costs no matter which raw material, green or dead trees, was used.

An earlier study (Mueller 1959) indicated that beetle-killed Engelmann spruce from Colorado could also be used in the manufacture of particle board.

Plywood

Deep surface checks and the lower moisture content of long-term dead trees preclude their use for peeling or slicing into veneer. However, trees that have recently died could probably be used in veneer production. The moisture content of wood to be made into veneer is critical and has a distinct effect on cutting (Lutz 1971). In general, wood with a moisture content above fiber saturation but not excessively high is best for cutting into veneer; the higher moisture content makes the wood more pliable. Species with a naturally uniform moisture content of about 50 to 60 percent cut well.

Some of the free water is forced out during cutting. This water apparently acts as a lubricant between the wood, the knife, and the pressure bar and aids the cutting process.

According to Lutz, the driest wood successfully cut into veneer at the Forest Products Laboratory was a flitch of teak with a moisture content of 25 percent. Veneer with pronounced checks was cut from air-dried ponderosa pine planks heated to about 200° F (93° C) in water and at a moisture content of about 15 percent Satisfactory veneer was cut from similar pine planks after they had been pressure-treated with water to a moisture content of over 100 percent

Wood Fuel

The principal use of wood worldwide is for fuel, and up until about 1850 wood was the dominant energy source in this country Today, the constantly increasing price of fossil fuels and other forms of energy is forcing industry and individuals to reevaluate their production and heating needs and to consider alternative energy sources. The wood-using industry has adapted to the changing economic situation by installing wood-fired boilers or cogeneration facilities that use the primary manufacturing waste formerly routed to the burner or landfill. Efficient stoves, readily available from a number of manufacturers, are being purchased by many homeowners.

The use of dead timber for fuel has several distinct advantages: the wood is dry, burns readily, and contains very little sulfur; the low moisture content results in a relatively high British thermal unit yield; and the ash residue has value as a soil supplement.

Dead timber is rarely harvested exclusively for fuel. The costs of removing dead trees are essentially the same as for harvesting green timber, and the dead timber's lumber and pulp chip values exceed the fuel value. However, the use of this wood by the individual homeowner is increasing along with the number of wood-fired stoves. The Northern Rocky Mountain Region estimates that in 1980 approximately 257 million board feet (73 759 m^3) of timber was removed from that Region's National Forests by persons desiring fuelwood.

Specifications for firewood are almost personal All species are used, although western larch and lodgepole pine are often favored. Many people want pieces that will not require splitting, are small-diameter and 18 to 24 inches (46 to 61 cm) in length. Dry wood, of course, is a basic requirement, and the standing dead trees are usually drier and preferred over the downed trees.

Land managers are using the firewood demand as a means of cleaning up harvested areas and as a way of reducing the fire hazard. The practice of yarding unutilized material (YUM) brings to the roadside much of the dead timber formerly left on the harvested area, and low-standard roads into dead timber stands allow access for firewood cutting. Both practices improve timber use and forest esthetics.

House Logs

The market for log homes has increased dramatically within recent years. Some 200 manufacturers produced about 20,000 log homes in 1979 and probably about 25,000 homes in 1980. Originally used as summer cabins or second homes, log homes are now being used as primary abodes. Several distinct advantages are associated with log homes. They are energy efficient, virtually maintenance free, and fairly durable (Business Week 1979). A well-designed home should last more than 100 years.

Although the majority of log structures use green tree logs, many log home manufacturers of the Rocky Mountain States are committed to using dead trees (fig. 7). Logs made from these trees are usually relatively inexpensive and, because such logs have a lower moisture content, they are lighter in weight than green tree logs. The light weight makes them easier to handle with smaller, less costly equipment, and reduces their shipping cost. Logs with drying checks can be positioned to minimize their effect, and preservative solutions or stains can penetrate and coat all exposed wood surfaces Finally, structures made of dried logs have less dimensional change and are more stable than structures made from green logs, unless the green logs are air-dried for a rather long time. A typical set of criteria used for selecting house logs, essentially the same for both green and dead timber, are as follows (Peckinpaugh 1978):

1. Free from rot
2. No spiral checks
3. 1/4 inch (0.6 cm) maximum width checks
4. 7 inches (17.8 cm) minimum diameter
5. Minimum length 16 ft (4.9 m)
6. Straight, no crook, and minimum sweep
7. Maximum taper 3 inches in 40 ft (7.6 cm in 12.2 m).

Most dead tree house logs in the Northern Rocky Mountain area are obtained from western white pine and lodgepole pine. However, Engelmann spruce, Douglas-fir, and western larch are also used. Tree length lodgepole pine logs are preferred because the longer lengths permit cutting to the required sizes, and short, usable pieces can often be obtained from trees with spiral grain, sweep, crook, or excessive taper.

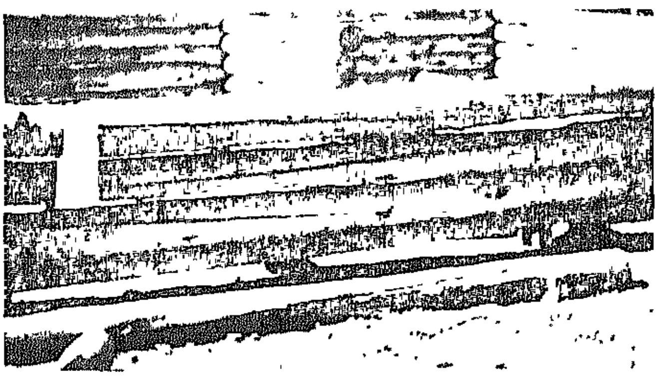

Figure 7.—Dead trees used in building log homes provide some advantages green wood logs lack.

Specialty Products

When dead trees are manufactured into lumber, the recovered boards are often of low quality and value. These traits deter the use of more of the dead timber resource. One way of increasing the value of this relatively low quality material is to promote its use for specialty products, such as interior paneling, picture framing, furniture, and decorative moldings. For these uses the differences between dead and green tree wood are accentuated and the uniqueness of the dead tree lumber emphasized. Such is the case for the marketing of white pocket veneer, pecky cypress; knotty pine; wormy chestnut; and gray, weathered barn wood

Research at the University of Idaho has focused on the use of dead western white pine tree lumber for specialty products (fig. 8) (Howe 1978; Christopherson and Howe 1979). Fourteen white pine logs from dead trees that had been in the log yard for at least 3 years were used in these studies. The logs had a gross Scribner log scale of 4,244 bd ft. and a net scale of 1,975 bd ft. The logs were cut into 2-inch and 1-1/4-inch (5.0- and 3 1-cm) thick dimension on a circular sawmill After drying, the pieces were resawed into paneling 7/16-inch (1.1 cm) thick.

The total volume of lumber recovered from the logs was 3,116 bd.ft ; however, much of this material was subsequently lost during resawing and surfacing. The volume of panel stock obtained was 1,416 bd.ft (0.41 m^3), with approximately another 1,000 bd.ft. (0.29 m^3) in short salvageable lengths The value of the paneling and other recoverable pieces was estimated to be considerably above that of the original dimension lumber.

Several mills in the Rocky Mountain area are producing specialty material from ponderosa and lodgepole pine (Howe 1978). The research cited above indicates that western white pine is also suitable for this use.

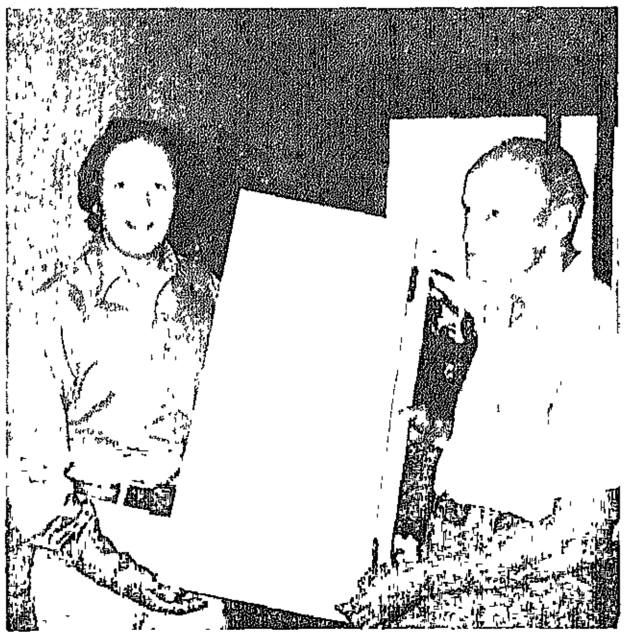

Figure 8.—High-value specialty products can be made from stained dead tree lumber. (Photo courtesy of University of Idaho.)

Chemical Utilization

Through the years, forest products and wood research have shown that many valuable foods and chemicals can be obtained from wood by means of chemical utilization. Most of these products require extensive treatment and are, therefore, costly to produce under the economic conditions of the early 1980's. However, in the event that chemical utilization becomes a reality, dead tree wood will be a valuable raw material.

SUMMARY

The overmature, unmanaged timber stands of the West contain an abundance of dead trees Catastrophic losses by insect and disease epidemics, fires, or violent windstorms often result in dead tree concentrations that can become focal points for salvage efforts But much endemic mortality can only be salvaged as a part of the regular harvesting of green timber Many of the dead trees contain usable wood and fiber decades after their death. Using the dead timber resource would do much to extend the available timber supplies and have a beneficial effect on subsequent forest management

The volume of dead timber and its suitability for manufacture is dependent to a large extent on the deterioration prior to harvesting Studies show that a number of factors can affect the rate of wood breakdown, including species, size of tree, amount of sapwood and heartwood, rate of growth, age of tree, and environment or climate Deterioration also affects the physical appearance of dead trees, and criteria have been developed to estimate the length of time trees have been dead

The processing and use of many tree species depend on the inherent physical and mechanical properties as well as the chemical constituents of the wood. Limited studies of the properties and composition of dead tree wood indicate no inherent difference between this wood type and wood from green trees. Dead trees and logs are being used to produce solid wood products such as lumber, house logs, and posts and poles.

Grade-yield studies show that the lumber recovered from dead tree logs is lower in value, quality, and quantity than lumber produced from comparable green tree logs. Also, the longer the time interval between death and utilization, the lower the value of the material recovered. The manufacture of specialty products is one way of enhancing the value of dead tree lumber.

House logs, posts, rails, and poles are other potential uses for dead trees Dead lodgepole pine trees are preferred by many Rocky Mountain log home manufacturers. Posts and poles made from dead trees can often be treated immediately with a preservative without long air-seasoning, and evidence indicates shorter treating schedules can be used to treat these products.

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The abundant quantity of dead trees in the western National Forests constitutes a resource that may help alleviate present and future timber shortages A general understanding of the characteristics of this resource and of the wood deterioration process may help provide more complete use. This paper summarizes information obtained from numberous studies of the tree deterioration process and reports results of recent investigations on the uses of dead trees

KEYWORDS: dead softwood timber, deterioration of dead trees, utilization of dead trees